Commercial selective harvest of coho salmon and chinook salmon on the Willapa River using tangle nets and gill nets.

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Final report – IAC contract 01-1018N
July 1, 2002

Abstract

Selective fishing is the ability of a fishing operation to avoid non-target species or stocks, or when encountered, to capture and release them in a manner that minimizes mortality. The tangle net was tested on the Willapa River to selectively harvest adult chinook salmon (*Oncorhynchus tschawytscha*) and coho salmon (O. *kisutch*). Experienced gill netters simultaneously fished tangle nets (3.5” mesh size) and conventional gill nets (5.75” mesh size) to evaluate their effectiveness for live release of non-target stocks. Live fish were tagged and released for recovery in sport fisheries, commercial fisheries, at hatchery racks and traps, and during spawning ground surveys. The tangle net was as effective for capturing coho salmon as the conventional gill net, and fish were generally captured in good condition. The immediate survival (from capture to release from the boat) of adult coho salmon captured in the gill net was 89.6%, compared to 86.8% from the tangle net. Coho salmon released from the tangle nets were recovered at about 22.7%, compared to 25.5% from the gill net. Significantly more non-target species were captured in the tangle net than the gill net. These tests showed that using conventional gill nets with short soaks and careful fish handling results in the same immediate and post-release survival of coho as using these techniques with the tangle net.

Purpose

Many salmon populations in the Pacific Northwest are declining to historically low levels. The causes of these declines vary by area, but typically include habitat destruction, mismanagement of harvest, interference by hatchery programs, and hydroelectric development. In Washington, numerous stocks are listed as threatened or endangered under the United States federal Endangered Species Act.

Throughout Washington, weak stocks of salmon return to their natal rivers to spawn intermingled with healthy stocks. Selective harvest technologies and practices allow a continued harvest, while protecting weak stocks. "Selective fishing", more accurately described as “live capture, selective harvest”, is the ability of a fishing operation to avoid non-target species or stocks, or when encountered, to capture and release those animals in a manner that minimizes mortality. Successful selective fishing requires that two objectives be met. First, a conservation goal must be achieved for the species or stock of concern, and second, a harvest goal must be met to make the fishery economically viable. Harvesting salmon with gill nets in these mixed stock fisheries is a problem because fishers inadvertently catch weaker species and stocks while targeting salmon from stronger runs. Because successful live release of salmon from a gill net is difficult, the only practical way these traditional gears can be more selective for the target species is by time and area closures. While these restrictions can be very efficient at reducing by-catch and meeting the conservation goal for the fishery, they necessarily reduce fishing opportunity for the target species and do not meet the harvest goals.

With the current management strategies, large surpluses of harvestable salmon are returning to hatcheries without being harvested. If the harvest strategies are not adjusted, producing fish for commercial fisheries should be reconsidered. We therefore began working with the commercial fishing industry to develop acceptable live capture gears that will provide more fishing opportunity while continuing to protect weak stocks. Simultaneous with the development of selective fishing methods, large portions of the hatchery production of coho salmon are being identified by the excision of the adipose fin before release as juveniles. When these fish return as adults, fishers can distinguish them from naturally produced fish that do not have the adipose fin removed.

The tangle net (Figure 1) is a possible substitute for gill nets that may meet the criteria for selective fishing. Tangle nets look similar to a gill net with a small mesh size (3.5” compared to 5.75” in a conventional coho salmon gill net). Tangle nets are made from multifilament web while gill nets are typically made from monofilament web. Both gears are fished in the same method and locations, but the similarities stop there. Unlike a gill net, which captures an adult salmon around the gills or body, the mesh size of the tangle net prevents adult fish from entering the net that far. Instead, the fish is caught by the maxillary or teeth, which allow it to continue respiring in the net so it can be released live. External and associated internal injuries are also reduced using this capture method. Modifications in fishing practices, including the use of fish revival boxes, short soak times, and careful fish handling, are as important as the gear in ensuring that fish are released live and unharmed.

Figure 1. Conventional gill net (left) compared to a tangle net (right).

The untested premise of live capture, selective harvest is that the released fish survive to contribute to rebuilding their stock. It is assumed that fish released in good condition will survive, but there have been no published studies looking at the long-term survival of fish that have been captured and released from commercial gill nets. Studies evaluating the survival of fish captured in sport fisheries indicate that mortality of released fish is variable and depends on the species captured, the skill of the fisher in releasing the fish, the environment, and the fishing method (Muoneke and Childress 1994). Survival of lake trout captured in gill nets in Lake Superior and held in tanks for 48 hours varied seasonally from 68% to 77% (Gallinat et al. 1997) and studies evaluating coho salmon released from commercial fishing gears in British Columbia have shown that mortality of fish held in net pens for 24 hours was less than 3% (Farrell et al. 2001a). However, evaluations of post-release survival of salmonids held in net pens are unlikely to reflect the post-release survival of free-swimming fish, because the fish in net pens are not subject to predation, currents, or encounters with obstacles to migration (e.g. dams, shallow parts of rivers, etc.) which a severely stressed fish, such as those captured in gears (Farrell et al. 2000) must contend with. Many tagging studies evaluating migration and population sizes suggest that fish can be captured and released with some successful survival, but these types of studies were not specifically directed at looking at the effects of the capture gears on survival.

The main goal of this study was to test the fundamental assumption of selective fishing – that the released fish we are trying to protect really do survive at acceptable levels to contribute to rebuilding the weak stocks they are part of – by comparing the post-release mortality of coho and chinook salmon released from tangle nets and conventional gill nets on the Willapa River. We also estimated and compared the immediate mortality and catch efficiency of the two gears and evaluated characteristics of fish caught in each gear. Gear changes may result in encounters with different non-target species (by-catch), and this is expected with the tangle net because many small fish species that dwell in the Willapa River can pass through the large mesh gill nets without incident, but would be captured in the smaller-meshed tangle net. Because it is undesirable to shift the impacts from one species to another, we also compared the capture of non-salmonid species in each gear.

Approach

We fished for coho salmon and chinook salmon from the mouth of the Willapa River to river mile (RM) 5, near South Bend, Washington (Figure 2). The lower river is subject to tides, and salt or brackish water reaches 18.1 miles from the river mouth upstream to Mill Creek. There is a WDFW salmon hatchery located on Forks Creek near its confluence with the Willapa River at RM 31.

We contracted three local fishers who had many years of experience gillnetting for salmon in the study area. They were asked to mimic the normal fishery pertaining to the location and how nets were laid out. They fished nets constructed from 80 fathoms of 3.5" tangle net shackled to 80 fathoms of 5.75" conventional gill net commonly used in this area for catching coho salmon. We used a monofilament single-strand mesh hung at a ratio of 2:1 (gillnet) and a four-strand 1.5 mm multifilament mesh hung at a ratio of 3:1 (tangle net). The hang ratio describes the amount of mesh relative to the corkline. The gill net measured 45 meshes deep and the tangle net measured 74 meshes deep so that both nets fished to the same depth. The nets were light green and the depths of the nets were suitable to the area being fished. Each vessel was equipped with a hydraulic reel mounted in the bow that was used to deploy and retrieve the nets. Fishing occurred during daylight and at optimal tides. Vessels fished simultaneously and near each other to mimic the fishery and to maximize the probability of recaptures.

Each set we switched the end of the net that was closest to shore so that the fishing effort of each net type was similar for each area fished. The nets were laid out in a curved pattern across the river and allowed to drift freely. WDFW observers selected the appropriate soak time (the time from when the first cork was laid out until we began to retrieve the net) for each set. The set time was defined as the time from when the first cork went into the water until the last cork was removed from the water.

All the vessels were equipped with a recovery box for reviving weak fish. The boxes were constructed of 0.5” marine grade plywood painted black. Each box had two rectangular compartments for holding fish. The compartments measured about 38.5” long, 11.5” high and 6.75” wide. The compartments were wide enough to allow a salmon to fit with its head facing the fresh water in-flow but narrow enough to prevent them from turning around. A 12-volt, 3800 g/hr submersible bilge pump was connected to the box with a 1.5” discharge hose which supplied fresh water to each compartment through pipes located at the bottom of the box. Overflow outlets were located at the top on the opposite end.

Two observers were on board each vessel during every fishing trip. One observer primarily recorded data, while the other handled fish. For each set, the following information was recorded: time when the first cork was put into the water, time when the first cork was removed from the water, time when the shackle was removed from the water, time when the last cork was removed from the water, location using a handheld global positioning unit, which net type entered the water first and which net type was removed from the water first. Other information recorded included the date, fishers name, boat name, observer names, set number, weather conditions, water and surface temperatures, presence of seals, and any other observations pertaining to a particular set.

Observers informed fishers when to start picking up nets. Fishers were instructed on proper handling of fish by avoiding touching the gill area or holding a fish by its caudal peduncle as they removed fish from the net. When possible, fishers looked over the bow as the net was pulling up so they could spot incoming fish and lift the fish over the roller. After removal from the net, fish were placed immediately into a tank of fresh water located near the bow. Any observations involving the handling of fish from net to tote were recorded.

For each coho or chinook salmon caught, we noted the species, the net type where it was captured, the type of capture, whether the adipose fin was missing, the condition at capture and the sex. We characterized the type of capture as follows: tangled by teeth or mouth, rolled in net, gilled, wedged (web around body further than gills), or mouth clamped (net wrapped around mouth, clamping it closed). At capture, a fish was considered to be in condition 1 if it was lively and not bleeding, condition 2 if it was lively but bleeding, condition 3 if it was lethargic but not bleeding, condition 4 if it was lethargic and bleeding, and condition 5 if it showed no movement or ventilation. Loss of scales, damaged fins and other visible injuries on fish were recorded. Fish ranking in condition 1 or 2 were tagged, measured and released overboard immediately. We used metal jaw tags (more commonly referred to as "hog rings") covered with a plastic sheath printed with a number. The plastic sheaths were color-coded to correspond to the net type where the fish was captured. We attempted to recover fish ranking in conditions 3, 4 or 5 to condition 1 or 2 before release. Some fish recovered unaided while in the holding tank. Other fish were assisted by placing a hose directly in the fish's mouth to force a constant the flow of fresh water across their gills. Other fish in need of recovery were placed into a recovery box for revival. The time for revival, or the time until resuscitation failed and the fish was ranked as dead, was recorded. Dead fish were donated to a local food bank. Non-target species encountered during fishing were counted and recorded according to the net type where captured then released.

To study the effects of multiple recaptures, we placed recaptured fish into holding tubes for 24 hours. Recaptured fish are fish that had been caught, tagged, measured, and released in a previous set. A control fish, one captured for the first time, of same species and net capture type was also placed in a tube for 24 hours. The fish tubes were constructed of PVC pipes, measuring 36" long and 10" diameter. Water circulation through the tubes was maximized by 1.5" holes throughout the PVC, and hinged iron grates over each end functioned as a gate to place and remove fish. We recorded the date of capture, tag color and number and the time it was placed in the tube. The tubes were then tied to a dock and positioned so fish were immersed in water. Fish were protected from seals and other predators while in the tubes. After 24 hours, we noted whether the fish was dead or alive, and released all live fish.

To evaluate the long-term survival of released fish, posters encouraging voluntary tag returns by anglers were placed near public fishing access areas requesting the date and location of harvest, the tag color, and the tag number. Commercial sampling surveys were conducted at fish buying stations in the Willapa Bay area. Staff at Nemah, Naselle and Forks Creek hatcheries collected jaw tags when coho and chinook salmon returned. In conjunction with regularly scheduled WDFW spawning ground surveys, we contracted with Pacific Conservation District to conduct additional spawning ground surveys to search for tagged salmon returning to the Willapa River. These surveys consisted of pairs of Pacific Conservation District crewmembers walking stretches of the upper Willapa River and many of the small tributaries in the Willapa drainage that were not normally surveyed by the WDFW spawning ground surveys. They took GPS coordinates at the start and finish of survey stretches and also noted survey time and river miles surveyed.

To observe potential fish size selection in each net, we compared the fork lengths of male and female adipose clipped coho caught in each net type to the fork lengths of male and female adipose clipped coho returning to Forks Creek Hatchery. The fork length and post-orbital hypural lengths collected from dead coho salmon from the test fishery were compared to the fork and post-orbital hypural lengths with returning hatchery coho salmon to observe differences resulting from fish maturation.

Findings

We fished near the mouth of the Willapa River in the vicinity of South Bend (Figure 2) for 13 days between 4 September and 16 October 2001. We captured 816 coho salmon (including 30 recaptures) and 226 chinook salmon (including 3 recaptures) in 379 sets (Table 1). The immediate mortality of adult coho salmon in the tangle net was not significantly different than that of coho salmon captured in the gill net (χ^2=2.44, df=1, P=0.12), but the immediate mortality of chinook salmon captured in the gill net was significantly greater than that of chinook salmon captured in the tangle net (χ^2=4.7, df=1, P=0.03).

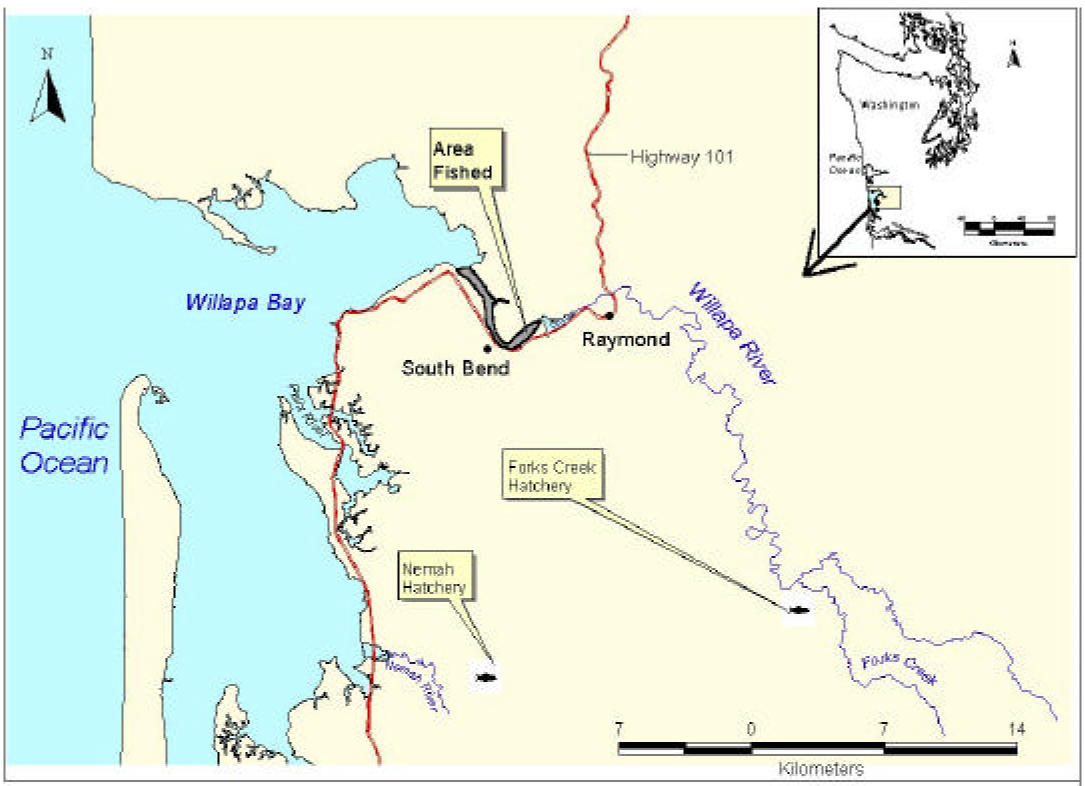

Figure 2. Location of test fishing on the Willapa River

Table 1. Capture and immediate mortality (the fish died before it could be released) of coho and chinook salmon in the 3.5” tangle net and the 5.75” gill net on the Willapa River.

	Mesh Type	Dead	Live	Total	% Mortality	95% Conf. Interval
Coho Adults	Tangle	51	342	393	13.0	10.0 - 16.7
	Gill	35	346	381	9.2	6.7 – 12.5
Coho Jacks	Tangle	3	35	38	7.9	2.7 – 20.8
	Gill	2	2	4	50.0	15.0 – 85.0
Chinook Adults	Tangle	4	105	109	3.7	1.4 – 9.1
	Gill	13	89	102	12.8	7.6 – 20.6
Chinook Jacks	Tangle	3	11	14	21.4	7.6 – 47.6
	Gill	0	1	1	0	0 – 79.4

Overall, we observed no improvement in the condition of coho salmon at capture in the tangle net compared to the gill net (comparing proportions of fish captured in conditions 1 or 2 in each net; χ^2= 0.14, df=1, P>0.05; Table 2). However, because the gill net tends to capture fish around the gills (Table 3), significantly more coho salmon were bleeding at capture (condition 4) in the gill net than in the tangle net (G=16.34, P=0.001). In contrast, chinook salmon were captured in significantly better condition in the tangle net than in the gill net (comparing proportions of fish captured in conditions 1 or 2 in each net; χ^2= 5.31, df=1, P<0.05). Chinook salmon captured in the tangle net had a significantly higher proportion of condition 1 (G=24.89, P<0.001), while chinook captured in the gill net had significantly higher proportions of conditions 3 and 5 (G=4.24, P=0.05; G=9.82, P<0.05 respectively, Table 4).

Table 2. Condition and recovery of adults captured during test fishing. % Cap is the percentage of the total captures in each condition, and % Rel is the percentage of each group released live.

		Condition at Capture														
Species	Net Type	**1**			**2**			**3**			**4**			**5**		
		% Cap	% Rel	N	% Cap	% Rel	N	% Cap	% Rel	N	% Cap	% Rel	N	% Cap	% Rel	N
Coho	Gill	50.1	100	192	3.4	92.3	13	27.8	95.2	105	5.7	86.4	22	13	50	50
	Tangle	54.8	100	233	1.4	100	6	31.8	89.8	137	0.9	100	4	11.1	25	48
Chinook	Gill	32	100	33	2.9	66.7	3	38.8	92.5	40	5.8	100	6	20.4	57.1	21
	Tangle	65	100	80	0.8	100	1	26.2	93.7	32	1.6	50	2	6.5	50	8

Table 3. Capture types of adult coho salmon.

	Gill Net				Tangle Net			
Capture Type	Captured		Dead		Captured		Dead	
	%	N	%	N	%	N	%	N
Gilled	45.1	172	75.7	28	7.8	43	13.2	7
Mouth Clamped	3.2	12	10.8	4	10.7	45	34.0	18
Tangled	16.8	64	10.8	4	75.3	317	49.1	26
Wedged	34.9	133	2.7	1	6.2	26	3.8	2

Table 4. Capture types of adult chinook salmon.

Capture Type	Gill Net				Tangle Net			
	Captured		Dead		Captured		Dead	
	%	N	%	N	%	N	%	N
Gilled	52	51	33.3	4	7.4	9	14.3	1
Mouth Clamped	8.2	8	33.3	4	5.0	6	0	0
Tangled	28.6	28	16.7	2	84.3	102	71.4	5
Wedged	11.2	11	16.7	2	3.3	4	14.3	1

Ninety-one coho died before they could be released (54 in the tangle net, 37 in the gill net). Adult coho that died after capture in the tangle net tended to be shorter (61.3 cm, N=52) than adult coho released live from the tangle net (64.8 cm, N=362; t=2.80, df=78, $P<0.05$), but there was no difference in the fork lengths of dead (68 cm, N=34) or live (68.7 cm, N=336) coho captured in the gill net (t=0.45, df=36, $P>0.05$). The set length was not related to the occurrence of dead coho in the tangle net (31 min mean set length with dead coho, N=54; 30 min mean set length without dead coho, N=374; t=0.74, df=91,$P>0.05$) or the gill net (32 min mean set length with dead coho, N=37; 30 min mean set length without dead coho, N=345; t=1.48, df=38, $P>0.05$).

Twenty chinook died before they could be released (7 in the tangle net, 13 in the gill net). Dead chinook adults captured in the tangle net tended to be smaller (58.3 cm, N=7) than chinook released from the tangle net (76.5 cm, N=116; t=2.95, df=121, P=0.004). This likely reflects different capture methods for smaller fish which tend to be gilled in the tangle net, and would sustain considerable injury compared to a fish which is tangled in the net. The mean fork length of dead chinook adults in the gill net (78.2 cm, N=9) was not significantly different from the mean fork length of the released fish (77.3 cm, N=90; t=0.29, df=97, $P>0.05$). The set length was not related to the occurrence of dead chinook in either the tangle net (30 min mean set length with dead chinook, N=7; 28 min mean set length without dead chinook, N=116; t= 0.99, df=121, $P>0.05$) or the gill net (28 min mean set length with dead chinook, N=13; 28 min mean set length without dead chinook, N=90; t=0.67, df=101, $P>0.05$).

We compared the catch efficiency of the tangle net to the gill net using the total catch of coho and fall chinook for all three fishers for each day we fished (Table 5). The tangle net had a higher catch efficiency than the gill net for coho and chinook salmon (Wilcoxon signed–rank test; $T_-=10$, n=13, $P<0.05$, $T_-=15$, n=13, $P<0.05$ respectively). This indicates that switching to tangle net gear could improve harvest numbers over the gill net when short soaks are used.

Table 5. Capture of adult coho and chinook salmon per hour (CPH) during comparable sets for each net type. The time fished includes only the time when the nets were in the water, and excludes the time spent traveling between sites.

Capture Period	Species	Net Type	Minimum CPH	Maximum CPH	Average CPH	Number of Sets
9/4/01- 9/12/01	Coho	Tangle	1.24	3.22	1.99	161
		Gill	0.91	2.06	1.48	161
	Chinook	Tangle	0.59	2.88	1.39	161
		Gill	0.82	2.80	1.32	161
10/4/01- 10/16/01	Coho	Tangle	1.47	4.87	3.38	218
		Gill	0.44	5.65	3.22	218
	Chinook	Tangle	0.06	0.65	0.28	218
		Gill	0.00	0.44	0.18	218

During our test fishery, we were capturing fish that were just entering the Willapa River, and had not yet undergone all of the morphological changes associated with sexual maturation. However, we were interested in evaluating whether the tangle net and gill net were selecting a particular size subpopulation from the general returning population. The best measure of the general returning population was at Forks Creek Hatchery, but these fish could only be measured after they reached sexual maturity, and their fork lengths would not necessarily be comparable to those of the fish captured a couple of months earlier in the test fishery. We therefore measured post-orbital hypural lengths of the mature fish, and of a subsample of the dead fish killed during the test fishery, because this length should remain constant during maturation. However, using the post-orbital hypural length for comparison would greatly reduce our sample size, as this is difficult to obtain during a test fishery from unanesthetized fish. We therefore compared the differences in the relationships between the post-orbital hypural length and the fork lengths of fish killed during the test fishery and those returning to the hatchery (Figure 3). We found no significant difference in these relationships ($Z=1.58$, $P>0.05$) and concluded that we could compare the much more powerful data sets of fork lengths to look for size selectivity of the two nets.

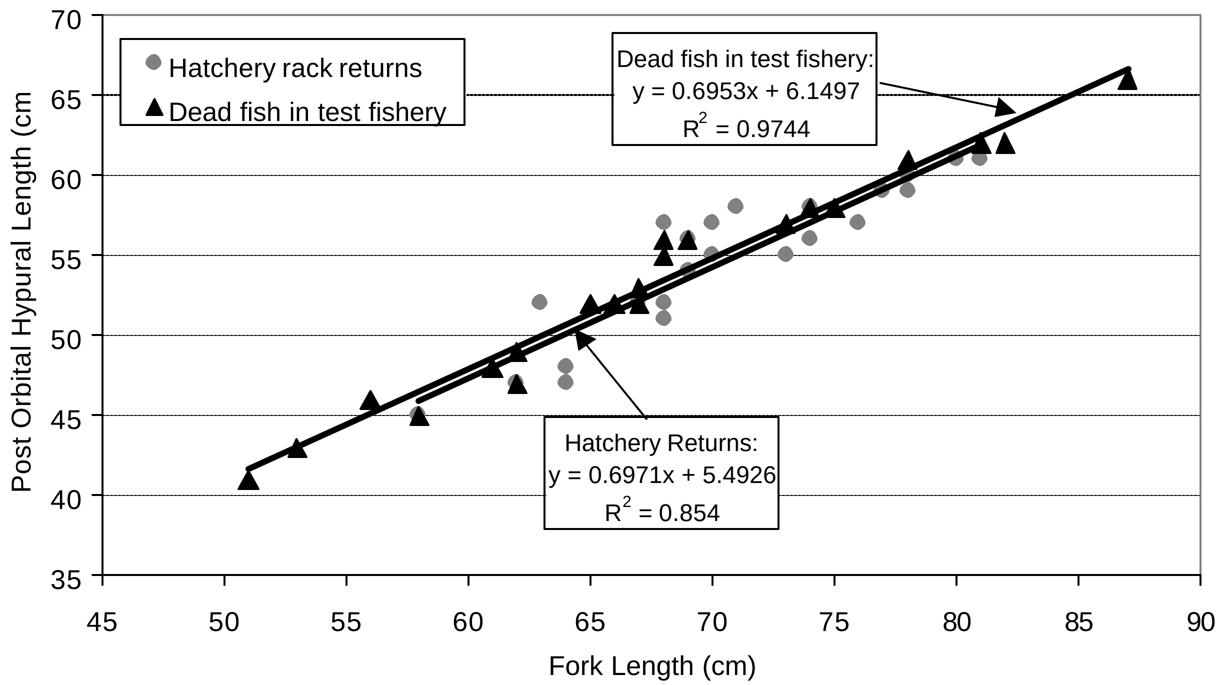

Figure 3. Relationship between the fork length and the post-orbital hypural length of coho salmon returning to the Willapa River captured in the test fishery or captured at the Forks Creek Hatchery rack.

Coho salmon captured in the tangle net were significantly smaller than those captured in the gill net (64.4 cm and 68.7 cm, respectively, $t=7.02$, $df=706$, $P<0.001$). There was no significant difference in the mean fork length between net types for chinook . Comparisons of the mean fork length between adipose clipped coho caught in the test fishery and adipose clipped coho returning to the Forks Cr. Hatchery showed that both net types displayed size selectivity in capture (Table 6). Both the tangle net and gill net captured significantly larger male coho than returned to the hatchery ($t=2.27$, $P=0.02$), while the tangle net captured significantly smaller female coho and the gill net captured significantly larger females than those that returned to the hatchery ($t=2.84$, $P=0.005$; $t=5.01$, $P<0.001$ respectively).

Table 6. Average fork length of adult coho by sex captured in test fishery and at Forks Creek Hatchery.

Sex	Net Type	Mean Test FL (cm)	N	Mean Hatchery FL (cm)	N
Male	Tangle	67.3	159	65.5	832
	Gill	68.0	151		
Female	Tangle	62.0	109	66.0	1011
	Gill	68.6	103		

The tangle net captured significantly more non-target species that the gill net ($\chi^2=373$, df=1; $P<0.001$; Table 7), but there was no significant difference in the number of salmonid bycatch between the net types ($\chi^2=0.13$, df=1, $P>0.05$). The actual numbers of non-salmonids are likely underreported because this was not the primary goal of the observers. The other non-target salmonids species encountered were generally released in excellent condition, while the condition of the other species was variable.

Table 7. Non-target species caught in the tangle and gill nets.

Species	Tangle Net	Gill Net
Anchovy, sardine, candlefish	755	7
Chum	84	79
Crab	62	23
Dogfish	26	2
Flounder	12	0
Shad	113	5
Steelhead	11	9
Other (less than 10 captured per species)	11	2

Twenty-five coho (14 recaptured, 11 controls-single capture) were held in fish tubes for 24 hours to judge the effects that recapture (being caught in more than one set) had on short-term survival. Of the 14 recaptures that were put into the tubes, 11 were released and three died (21.4%). Of the 11 control fish placed in the tubes, 7 were released and 4 died (36.4%). There was no significant difference in the short-term survival between single capture and recaptured fish ($\chi^2=0.14$, df=1, $P>0.05$). The higher survival rate of the recaptured fish, which is the opposite of what we would have expected, may have been an artifact of a small sample size.

There was no significant difference between the post-release survival of chinook ($\chi^2=0$, df=1, $P=1$) or coho salmon ($\chi^2= 0.05$, df=1, $P>0.05$) released from the gill net or the tangle net (Table 8). The first tag recovery was reported on 6 September, and the final tag was recovered on 20 November 2001 implying that the released fish can survive a long time after release. More than 80% of the tags recovered were from the Forks Creek Hatchery. The other tags were recovered in commercial samples taken in South Bend and from sport fishers in Willapa Bay and throughout the Willapa drainage (Figure 4). After an extensive stream survey effort of 80 man-hours and 104 river miles, only two tags were recovered from the spawning grounds. Two high water events in the Willapa River drainage during prime spawning ground survey time hampered potential jaw tag recovery from naturally spawned fish.

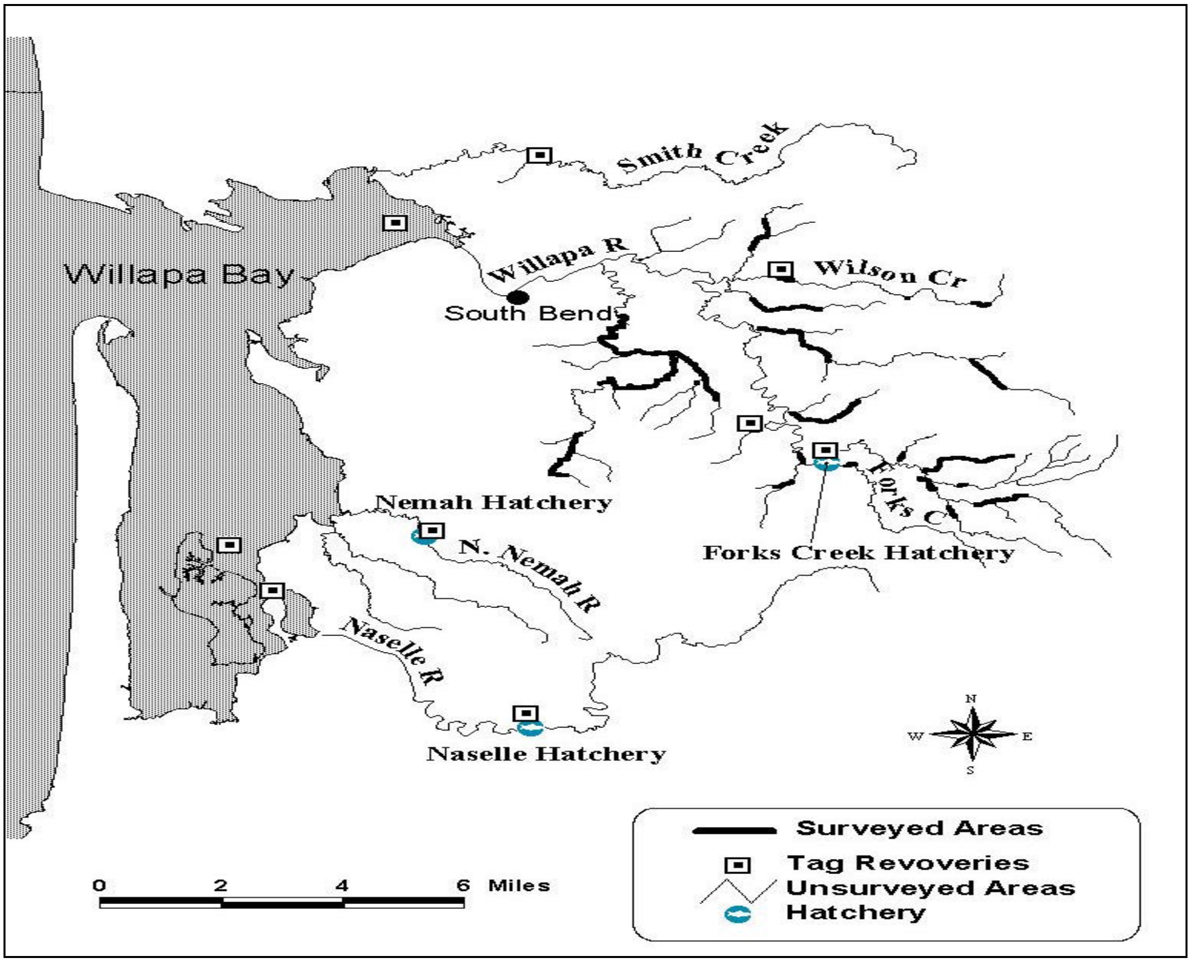

Figure 4. Map of study area showing location of stream surveys and jaw tag recoveries throughout the Willapa basin.

Table 8. Post release survival of fish captured and released from the tangle net and conventional gill net test fisheries.

		Tagged & Released	% Recovered (N)
Chinook salmon	Gill	86	10.47% (9)
	Tangle	103	10.68% (11)
Coho salmon	Gill	326	25.46% (83)
	Tangle	326	23.01% (75)

The long term survival of adult coho did not seem to be influenced by the date of release (t=0, df=12, P=1.0; Table 9), condition at capture (χ^2=2.87, df=4, P=0.58; Table 12), capture type

(χ^2=2.88, df=4, P=0.58; Table 11), or the skipper that operated the boat during release (χ^2=4.03, df=4, P=0.26; Table 12). The proportions of coho captured in each of these categories were not significantly different than the proportions of coho recovered for each category.

Table 9. Number of tagged adult coho released and recovered by date of release.

Date	Number Released	% Released	Number Recovered	% of Recovered
04-Sep-01	11	1.6%	5	4.3%
05-Sep-01	48	7.2%	8	6.8%
06-Sep-01	27	4.0%	10	8.5%
07-Sep-01	23	3.4%	4	3.4%
10-Sep-01	27	4.0%	3	2.6%
12-Sep-01	24	3.6%	8	6.8%
04-Oct-01	73	10.9%	13	11.1%
05-Oct-01	62	9.3%	10	8.5%
08-Oct-01	96	14.3%	17	14.5%
09-Oct-01	46	6.9%	6	5.1%
12-Oct-01	11	1.6%	0	0.0%
15-Oct-01	151	22.5%	26	22.2%
16-Oct-01	71	10.6%	7	6.0%

Table 10. Distribution of adult coho at release and recovery by condition at capture.

Condition at Capture	Number Released	% Released	Number Recovered	% of Recovered
1	393	58.7%	74	63.8%
2	13	1.9%	1	0.9%
3	209	31.2%	37	31.9%
4	19	2.8%	1	0.9%
5	36	5.4%	4	3.4%

Table 11. Distribution of adult coho at release and recovery by capture type.

Capture Type	Number Released	% Released	Number Recovered	% of Recovered
Gilled	155	23.3%	21	18.1%
Mouth Clamp	33	5.0%	4	3.4%
Rolled	10	1.5%	3	2.6%
Tangle	328	49.4%	62	53.4%
Wedged	138	20.8%	26	22.4%

Table 12. Distribution of adult coho at release and recovery by skipper.

Skipper	Number Released	% Released	Number Recovered	% of Recovered
1	250	37.3%	36	31.0%
2	185	27.6%	37	31.9%
3	166	24.8%	35	30.2%
4	69	10.3%	8	6.9%

Evaluation

Our results indicate that tangle nets do not provide a significant improvement in immediate or long-term survival of coho salmon compared to gill nets on the Willapa River when using short soak times, careful fish handling and recovery boxes. We did find that the immediate mortality of fall chinook salmon was lower using the tangle net than the gill net, but this did not translate to an improvement in the long-term survival of fall chinook salmon. Additionally, the tangle net was more effective for capturing chinook and coho salmon than the gill net. The tangle net may therefore be useful for capturing coho in instances where chinook require protection, but the effect on non-target species must also be considered. Based on this experiment, the ecological effects of a coho fishery would probably be minimized by using the gears currently in operation coupled with careful timing to avoid chinook, and implementing the use of short soaks, careful handling, and recovery boxes if any fish are to be released live.

Fish captured in the tangle nets were generally captured around the jaw and face, and suffered less body trauma than fish captured in the gill net. While this did not translate to improved survival, it may provide a more marketable product, equal in quality to fish captured by trolling. This aspect of the tangle net could be a way to improve the value of an ever-diminishing commercial fishery, and merits further exploration by the industry.

These results contrast sharply with a similar evaluation of the post-release survival of spring chinook salmon on the Columbia River (Vander Haegen et al. 2002). In that study, spring chinook captured and released from tangle nets survived at significantly higher rates than those captured and released from gill nets. Different species are known to have different responses to the same stressors (Schreck et al. 2001), and so may not respond to the nets in the same ways. A given species may also display a different response in a more stressful environment than a less stressful environment. In our study, the environment was likely unfavorable to capture and release because the water was relatively warm during the coho salmon migration. Fishing in better conditions (e.g. cooler, water, fewer predators) would most likely increase mortality, although we don't know the magnitude of the difference. On the Columbia River, the spring chinook were captured after they had migrated about 140 miles upstream, and were presumably habituated to the river environment. Coho salmon captured on the Willapa River were captured within 5 miles of the river mouth and may have been in a physiological transition between salt and freshwater, making them more susceptible to capture mortality.

The two-chambered recovery boxes used for lethargic fish were effective for recovering coho salmon. Farrell et al. (2001a) also found these types of recovery boxes effective for recovering coho salmon, although we were unable to achieve the 93.5% recovery of fish captured in gill nets in condition 5 (no visible movement or ventilation) that they observed. The reason for this difference is unclear, but may because of the capture method. Because the percentages of coho salmon released in each condition at capture were the same as the percentages recovered, it seems that our revival methods improved the physiological condition of the captured fish to a level similar to a fish captured in condition 1. Because a true physiological recovery requires much longer than the time for which we held fish, the post-release survival of any captured fish could probably be improved by holding fish for as long as possible, especially if the fish was brought on board in very poor condition, or by holding the fish in a cage alongside the vessel to promote active swimming during recovery (Farrell et al. 2001b).

In a selective fishery, a fish released by one fisher may be recaptured by another, resulting in additional mortality if the detrimental effects of capture are additive. We tried to evaluate the effects of multiple recaptures on the short-term survival of coho salmon, but in spite of having our test fishers fish near each other, our sample size of recaptured fish was small and the results are inconclusive. This is encouraging if it really means that most fish are captured only once.

Stream surveys were unsuccessful at recovering tags. High water events precluded surveys during some critical times compounding the difficulty in recovering coho carcasses. The 20% of tags we recovered mainly at the hatchery is clearly a minimal estimate of the survival, and is most applicable to hatchery fish. Released fish that attempt to spawn naturally may continue to be affected by capture – they may have difficulty competing with other spawning fish, or the gamete quality may be decreased. Further studies are required to investigate the effects of capture and release on spawning, and to estimate the post-release survival rates for fish captured and released from fishing gears.

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Acknowledgements

WDFW biologists Anita Swanson, Erik White, and Gil Lensegrav. WDFW technicians Shona Bruce and Keith Sweeney, and Pacific Conservation District technician Pok Vang collected data during test fishing. Eric Petit, Norris Petit, Bryan O'Shaughnessy, and Bruce Ogren provided expert test fishing on the Willapa River. Mike Johnson and his staff at the Pacific Conservation District, and WDFW staff led by Kurt Holt provided stream surveys. Patrick Verhey directed sport and commercial fishery sampling for jaw tags.